

APPENDIX H – Development of Soil Remediation Levels for the Golf Course Groundskeeper

H.1 Introduction

This appendix presents a summary of the approach used to calculate soil remediation levels for areas included in the golf course land use areas, assuming that an engineered cap is placed over the contaminated soil. The approach used to calculate these levels is the same as that used to calculate Site-specific cleanup standards presented in Chapter 3 of the Human Health and Ecological Risk Assessment for the Former DuPont Works Site (PIONEER, 2002).

The equations used to calculate soil remediation levels for the golf course evaluation units were obtained from the Model Toxics Control Act (MTCA) – Washington Administrative Code (WAC) 173-340-745. Soil remediation levels were calculated using these equations considering the potential reasonable maximum exposure for golf course groundskeepers who may occasionally contact contaminated soil beneath the cap during intrusive maintenance activities, such as repairing sprinkler lines.

The Environmental Protection Agency (EPA) has chosen to evaluate the potential health effects of lead using a physiologically based model. Therefore, lead has not been assigned the toxicity values required to calculate Site-specific remediation levels using the equations presented in WAC 173-340-745. The model developed by EPA for establishing lead remediation levels in non-residential areas is the Adult Lead Model (EPA, 1996).

H.2 Development of Soil Remediation Levels for Golf Course Groundskeepers

The equations and input values used to develop soil remediation levels for golf course groundskeepers potentially exposed to constituents of concern (COCs) identified in the RA (other than lead) based on incidental soil ingestion are presented below.

Equation for Noncarcinogens:

$$\text{WAC 173-340-745-1 – Soil Remediation Level (mg/kg)} = \frac{RfD \times ABW \times UCF \times HQG \times AT_n}{SIR \times AB1 \times EF \times ED}$$

Equation for Carcinogens:

$$\text{WAC 173-340-745-2 – Soil Remediation Level (mg/kg)} = \frac{CRG \times ABW \times AT_c \times UCF}{CPF \times SIR \times AB1 \times EF \times ED}$$

Where;

Parameter	Description
EF	= Exposure Frequency (days/year)
ED	= Exposure Duration (years)
SIR	= Soil Ingestion Rate (mg/day)
AB1	= Gastrointestinal Absorption Fraction (AB1) (unitless)
ABW	= Body Weight (kg)
ATn & ATc	= Averaging Time (days)
RfD	= Noncarcinogenic reference dose (mg/kg-day).

CPF	= Cancer potency factor (mg/kg-day) ⁻¹ .
UCF	= Unit conversion factor (mg/kg).
HQG	= Hazard quotient goal (i.e., 1)
CRG	= Cancer risk goal (i.e., 1E-05).

H.2.1 Equation Input Values

The input values for these equations consist of exposure factors, which describe the exposure patterns of the receptors (i.e., exposure frequency, exposure duration, ingestion rate, gastrointestinal absorption fraction, body weight, and averaging time); toxicity values (i.e., reference doses and carcinogenic potency factors), and benchmark values (i.e., target hazard quotients and target cancer risks). These input values are discussed below.

H.2.2 Exposure Factors

Exposure factors are used to estimate the likely intake level of a constituent. The exposure factors used to calculate remediation levels were approved by Ecology (Ecology, 1998) and are described below:

- *Exposure Frequency (EF)* – The number of days per year that a person is exposed. For the golf course groundskeeper exposure is assumed to occur 12 days/year (i.e., once per month).
- *Exposure Duration (ED)* – The number of years over which exposure is assumed to occur. For the golf course groundskeeper the exposure duration was assumed to be 20 years, which is the MTCA default value for worker exposure duration.
- *Soil Ingestion Rate (SIR)* – The amount of soil ingested per day of exposure. For the golf course groundskeeper the soil ingestion rate was assumed to be 100 mg/day.
- *Gastrointestinal Absorption Fraction (AB1)* – This is the percentage of a constituent that is available for absorption by the gastrointestinal tract once ingested. This is typically a constituent-specific value, but based on direction given by Ecology this value was conservatively chosen to be 100% for all constituents.
- *Body Weight (ABW)* – The average body weight, in kilograms, of the receptor being evaluated. For the golf course groundskeeper this value was assumed to be the MTCA default of 70 kg, the average weight of an adult (average of both females and males).
- *Averaging Time (Atn and Atc)* – The number of days over which exposure is averaged. Exposure levels for carcinogens are averaged over the lifetime of the exposed individual (i.e., 75 years) while exposure levels for noncarcinogens are averaged over the duration of exposure. Therefore, for carcinogens, the averaging time is calculated as the exposure frequency (days/year) X 75 year life expectancy. The averaging time for noncarcinogens is calculated as the exposure frequency (days/year) X exposure duration (years).

The exposure factors used to calculate soil remediation levels are presented in Table H-1.

H.2.3 Toxicity Values

The toxicity values used to develop soil remediation levels include noncarcinogenic reference doses (RfDs) and carcinogenic potency factors (CPF) are presented in Table H-1. The following sources of toxicity information were consulted to identify the toxicity values used to develop the soil remediation levels:

- The Integrated Risk Information System (IRIS) (EPA, 2001).
- The Health Effects Assessment Summary Tables—Annual Update (HEAST) (EPA, 1997).
- Ecology's Cleanup Levels and Risk Calculation (CLARC) Table Updates (Ecology, 2001a).
- EPA Region IX Preliminary Remediation Goal (PRG) Tables (EPA, 2000).

Since multiple toxicity values were available for some chemicals, the sources of toxicity information were prioritized as follows to select the toxicity values used in the development of soil remediation levels:

1. IRIS values.
2. HEAST values.
3. CLARC table values.
4. PRG table values.

H.2.4 Benchmark Values

The last category of equation input values are the risk benchmark values, used to define the “acceptable” risk level for a person exposed to Site contamination. The benchmark values used are the hazard quotient goal (HQG), which is the benchmark for noncarcinogenic effects, and the cancer risk goal (CRG), which is the benchmark for carcinogenic risk. A description of these values is presented in Chapter 3 of the RA. In calculating soil remediation levels for the golf course groundskeeper, the benchmark values used were a HQG of 1.0 and a CRG of 1 in 100,000 (i.e., 1E-05) for individual constituents. These are the benchmark values for industrial exposures stipulated in MTCA (WAC 173-340-745).

H.3 Development of Soil Remediation Levels for Lead

EPA’s Adult Lead Model used to calculate soil remediation levels for lead is described in Chapter 3 of the RA (PIONEER, 2002) and (EPA, 1996). The model input values used for the golf course groundskeeper are presented in Table H-2; the lead remediation level obtained from this calculation is presented in Table H-3 along with the other Site-specific remediation levels calculated for golf course development.

Table H-1 – Soil Golf Course Groundskeeper Soil Remediation Levels

Constituent	RfD ⁽¹⁾	CPF ⁽¹⁾	ABW ⁽²⁾	Atn ⁽²⁾	Atc ⁽²⁾	UCF ⁽²⁾	SIR ⁽²⁾	AB1 ⁽²⁾	EF ⁽²⁾	ED ⁽²⁾	HQG ⁽³⁾	CRG ⁽³⁾	Soil Remediation Level (Noncarcinogen) (mg/kg)	Soil Remediation Level (Carcinogen) (mg/kg)
Monomethylamine Nitrate	0.0081		70	7,300		1.0E+06	100	100%	12	20	1		172,463	
Nitroglycerine		0.014	70		27,375	1.0E+06	100	100%	12	20		1.0E-05		57,031
2,4,6-Trinitrotoluene	0.0005	0.03	70	7,300	27,375	1.0E+06	100	100%	12	20	1	1.0E-05	10,646	26,615
Aluminum	1		70	7,300		1.0E+06	100	100%	12	20	1		21,291,667	
Arsenic (inorganic)	0.0003	1.5	70	7,300	27,375	1.0E+06	100	100%	12	20	1	1.0E-05	6,388	532
Copper	0.037		70	7,300		1.0E+06	100	100%	12	20	1		787,792	
Mercury	0.0003		70	7,300		1.0E+06	100	100%	12	20	1		6,388	
Benzo(a)anthracene		0.73	70		27,375	1.0E+06	100	100%	12	20		1.0E-05		1,094
Benzo(a)pyrene		7.3	70		27,375	1.0E+06	100	100%	12	20		1.0E-05		109
Benzo(b)fluoranthene		0.73	70		27,375	1.0E+06	100	100%	12	20		1.0E-05		1,094
Benzo(k)fluoranthene		0.073	70		27,375	1.0E+06	100	100%	12	20		1.0E-05		10,938
Chrysene		0.0073	70		27,375	1.0E+06	100	100%	12	20		1.0E-05		109,375
Dibenz(a,h)anthracene		7.3	70		27,375	1.0E+06	100	100%	12	20		1.0E-05		109
Indeno(1,2,3-cd)pyrene		0.73	70		27,375	1.0E+06	100	100%	12	20		1.0E-05		1,094
Aldrin	0.00003	17	70	7,300	27,375	1.0E+06	100	100%	12	20	1	1.0E-05	639	47

Equation Input Values:

Input	Definition	Units
RfD	Noncancer Reference Dose	mg/kg-day
CPF	Cancer Potency Factor	(mg/kg-day) ⁻¹
ABW	Average Body Weight	kg
At _n	Averaging Time for Noncarcinogenic Effects	days
At _c	Averaging Time for Carcinogenic Effects	days
UCF	Unit Conversion Factor	mg/kg
SIR	Soil Ingestion Rate	mg/day
AB1	Gastrointestinal Absorption Rate	unitless
EF	Exposure Frequency	days/year
ED	Exposure Duration	years
HQG	Hazard Quotient Goal for Noncarcinogenic Health Effects	unitless
CRG	Cancer Risk Goal for Carcinogenic Health Effects	unitless

Notes:

⁽¹⁾RfDs and CPFs were obtained from (IRIS, 2001), (HEAST, 1997), (Ecology, 2001a), or (EPA, 2000).

⁽²⁾All exposure parameters were obtained from WAC 173-340-745 except the soil ingestion rate (SIR) and exposure frequency (EF). These are Site-Specific values.

⁽³⁾Risk goals were obtained from WAC 173-340-745.

Equations:

Noncarcinogenic Soil Remediation Level (mg/kg):
WAC 173-340-745-1

$$\frac{RfD \times ABW \times UCF \times HQ \times AT_n}{SIR \times AB1 \times EF \times ED}$$

Carcinogenic Soil Remediation Level (mg/kg):
WAC 173-340-745-2

$$\frac{Risk \times ABW \times UCF \times AT_c}{CPF \times ASIR \times B1 \times EF \times ED}$$

Table H-2 – Input Parameters and Results of the Adult Lead Model

Input Parameter	Units	Golf Course Groundskeeper Parameter Value⁽¹⁾
PbB _{fetal,0.95}	ug/dl	10
R _{fetal/maternal}	(unitless)	0.9
BKSF	ug/dl per ug/day	0.4
GSD _{i,adult}	(unitless)	1.81
PbB _{adult,0}	ug/dl	1.36
IR _s	g/day	0.100
AF _s	(unitless)	0.12
EF	days/year	52
AT	days/year	365
Results		
RBRG ⁽³⁾	ug/g	4,134 ⁽²⁾

Notes:

⁽¹⁾These Site-specific values were specified for use by Ecology (Ecology, 1997).

⁽²⁾This value was rounded down to 4,100 ug/g (note: 4,100 ug/g = 4,100 mg/kg).

⁽³⁾Risk-based remediation goal.

Table H-3 – Golf Course Groundskeeper Soil Remediation Levels⁽¹⁾

Constituent	Golf Course Groundskeeper Soil Remediation Level (mg/kg)
Explosives	
2,4,6-Trinitrotoluene ⁽²⁾	10,600
Inorganics	
Arsenic	530
Lead ⁽³⁾	4,100
Mercury ⁽⁴⁾	6,390
PAHs	
Benzo(a)Pyrene	109
Pesticides	
Aldrin	47

Notes:

⁽¹⁾Where remediation levels were calculated for both carcinogenic and noncarcinogenic effects, the value presented in the table is the lower of the two values. The soil remediation levels presented in Table 3 have been rounded down from the values shown in Table 1.

⁽²⁾Based on agreement with Ecology, the Site-specific cleanup level for 2,4,6-Trinitrotoluene is 1.75 mg/kg (Ecology, 2001b)

⁽³⁾Value was derived using EPA's Adult Lead Model (EPA, 1996).

⁽⁴⁾Based on agreement with Ecology, the Site-specific cleanup level for mercury is 24 mg/kg (Ecology, 1993).

H.4 References for Appendix H

- Ecology (Washington State Department of Ecology). 1993. Mercury Cleanup Levels Summary and Mercury/Lead Leaching Study. Letter from Mike Blum to Vern Moore, Linda Rudisel, and Jack Frazier. August 12, 1993.
- Ecology (Washington State Department of Ecology). 1997. Residential Soil-Lead Cleanup Standard for Former DuPont Works Site. Memo from Mike Blum to Vern Moore and Jack Frazier. October 1, 1997.
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- Ecology (Washington State Department of Ecology). 2001. Cleanup Levels and Risk Calculation (CLARC) Table Updates, Version 3.1, November, 2001.
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- EPA (United States Environmental Protection Agency) 1996. Recommendations of the Technical Review Workgroup for Lead for an Interim Approach to Assessing Risks Associated with Exposures to Lead in Soil. Technical Review Workgroup for Lead. Adult Risk Assessment Committee.
- EPA (United States Environmental Protection Agency) 1997. The Health Effects Assessment Summary Tables- Annual Update (HEAST): FY 1997 Update. EPA/540-R-97-036. PB97-921199. July. OSWER, Washington, D.C.
- EPA (United States Environmental Protection Agency) 2000. EPA Region IX Preliminary Remediation Goal (PRG) Tables. 2000 Update. <http://www.epa.gov/region09/waste/sfund/prg/>.
- EPA (United States Environmental Protection Agency) 2001. The Integrated Risk Information System (IRIS). Environmental Criteria and Assessment Office, Cincinnati, Ohio. 4th Quarter Update.
- PIONEER (PIONEER Technologies Corporation) 2002. Human Health and Ecological Risk Assessment for the Former DuPont Works Site, Dupont, Washington.